

KING'S MEDICAL ENGINEERING CENTRE

MRI Robotics & Haptics

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Wellcome Trust-EP SRC Medical Engineering Centre

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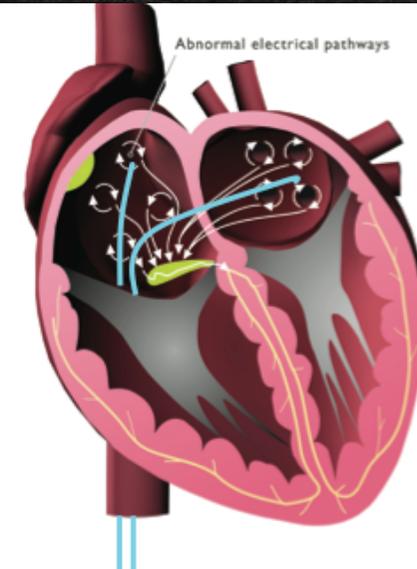
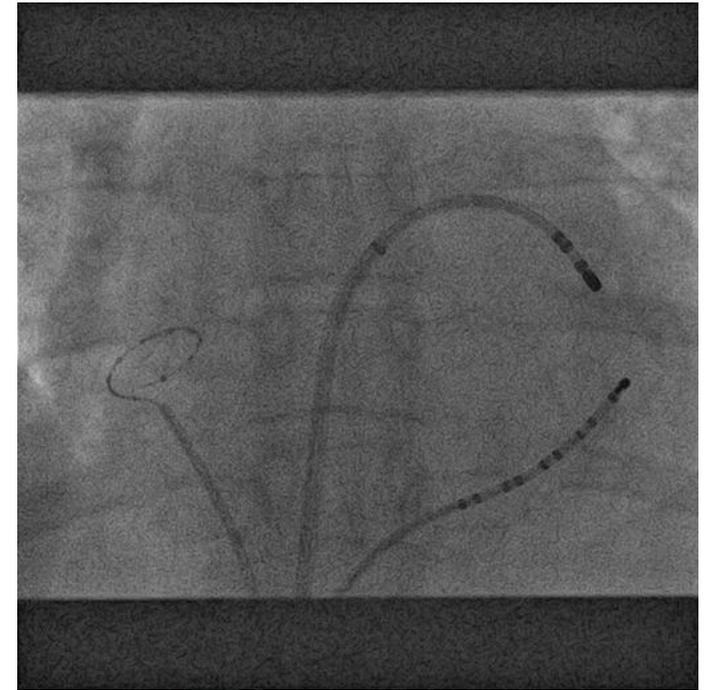
Technology Strategy Board
Driving Innovation

wellcometrust



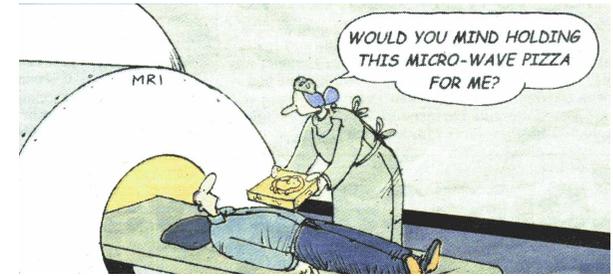
Current X-ray Guidance of Procedure

- Complex Procedure – high skills of user
- High radiation due to long X-ray time (4h)
- Less information about anatomy
- Varying outcome
 - Steering of catheter
 - Mechanical contact
 - Lesion assessment



AIM : Development of a Robotic and MR-Guided EP-procedure

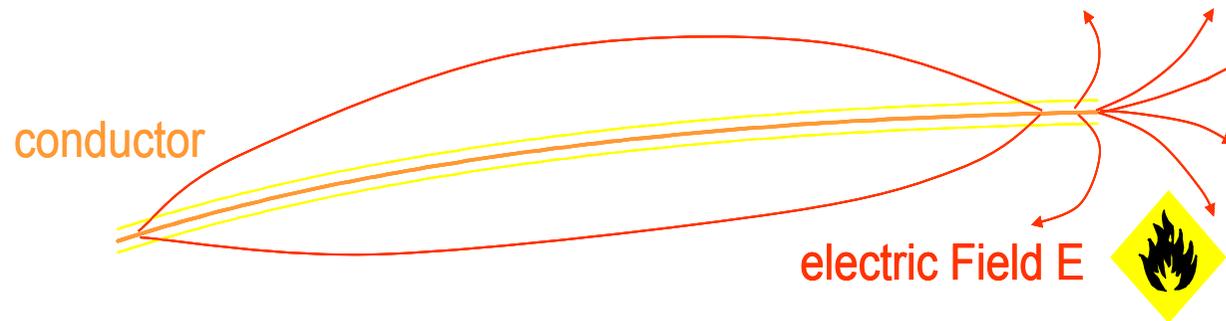
- 2-DOF Steerable Catheter to Avoid rotation of shaft
- Modifiable Curvature Without an Extra Sheath
- Stiffness Adjustability
- 7-9 Fr (2.3 - 3 mm) outer diameter
- Integration of the Tip Force Sensor
- MR-Compatible



MR-compatibility – RF heating of Conductors

- RF transmission couples electrically to conductor
- Local heat dissipation $\propto \sigma_{\text{tissue}} E^2 \Rightarrow$ maximal at tip
- $T = 20\text{-}70^\circ\text{C}$ for bFFE sequence with SAR at 3.9W/kg

No conductive wires are allowed!



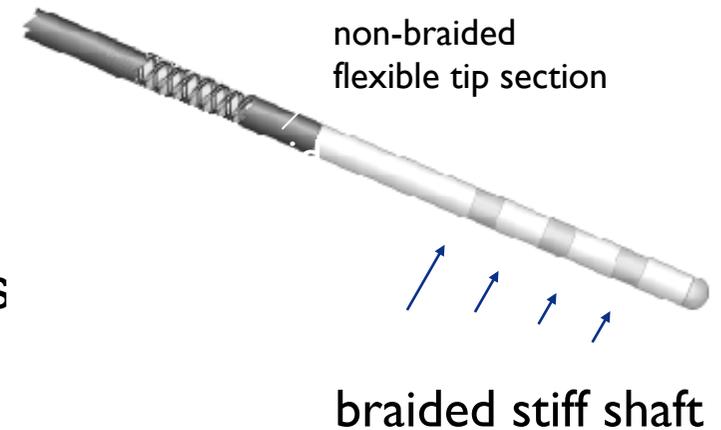
Ladd M et al. ISMRM 1998, p.473

Buecker A. Minim Inv Ther 2006;15(2):65-70

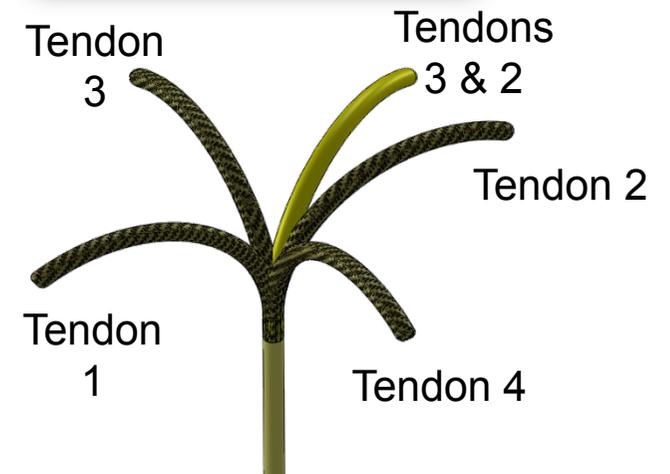
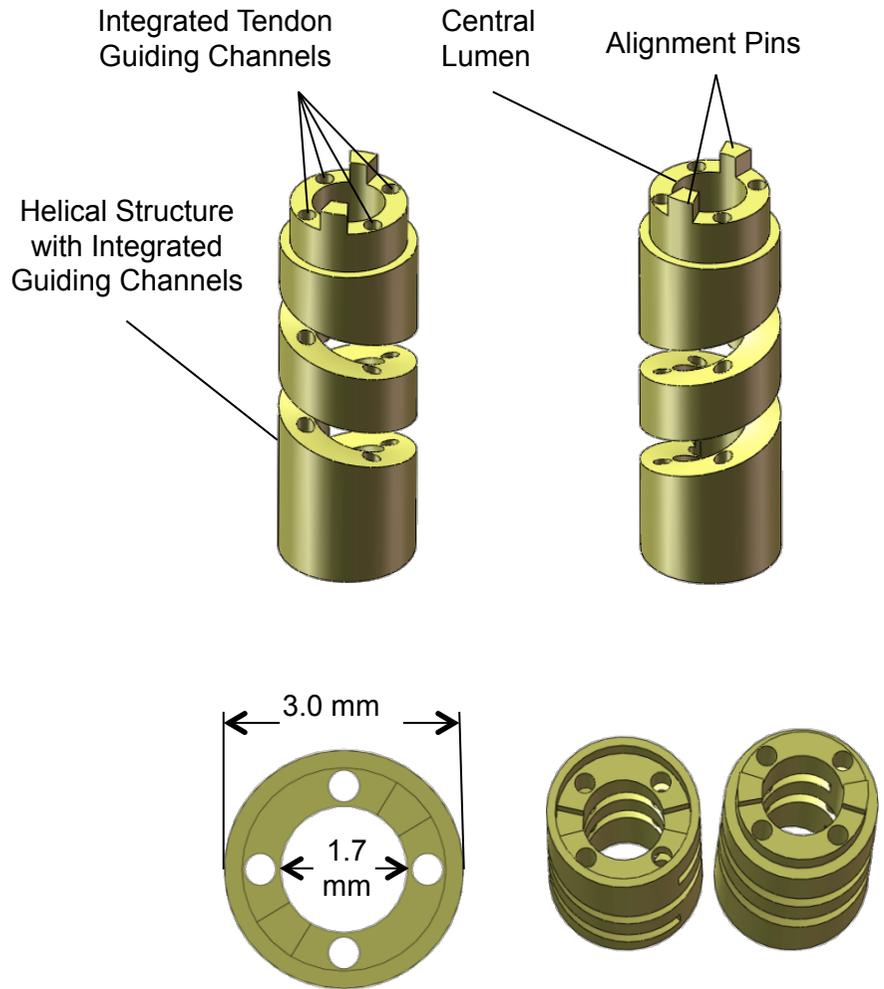
Catheter Devices

Mechanical stability and steering

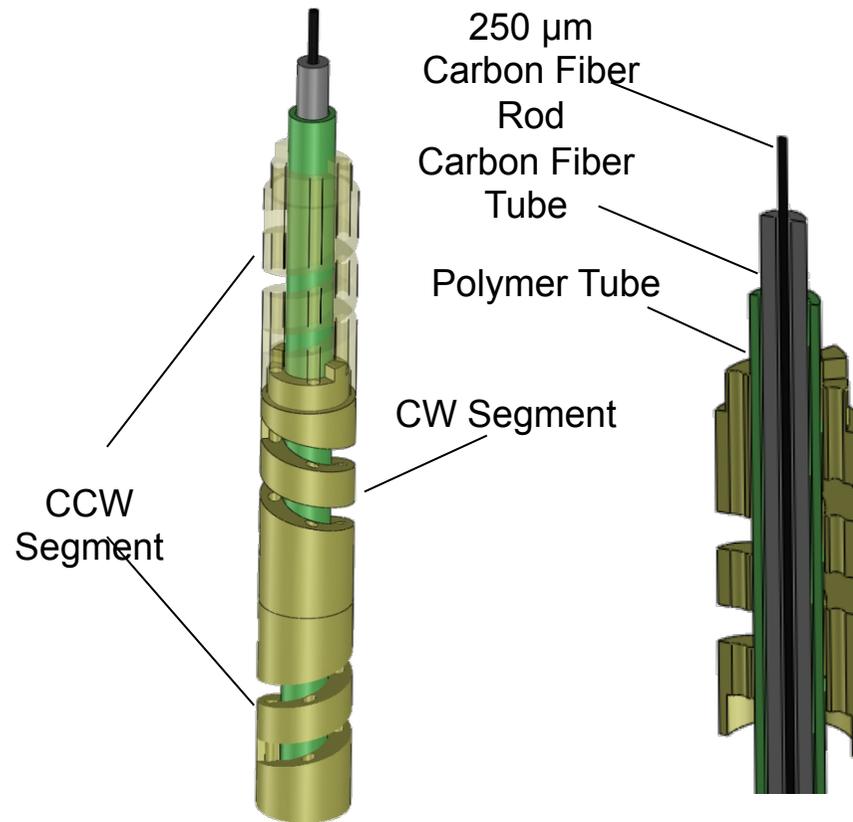
- Metallic braids in catheter tubes
 - Torqueability
 - Kink resistance
 - Pressure resistance of lumen
- Steering Wires
- Wires in EP catheters
 - Internal ECG,
 - cardiac pacing,
 - RF ablation + temperature sensors
 - Force Sensors



Mechanical Design: 3-DOF Segment Based Steering



Mechanical Design: Steering Mechanism Assembly



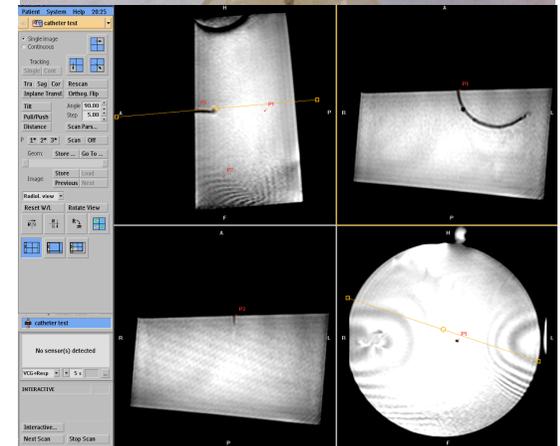
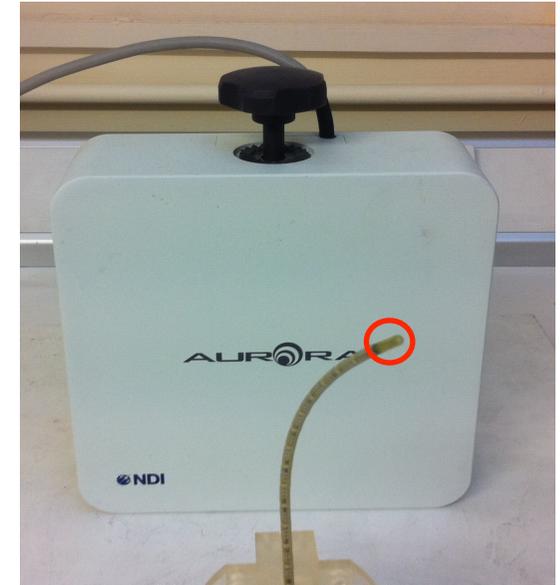
Experiments

1. Lab-based accuracy measurement

- Magnetic tracking system (NDI Aurora)
- Tip position and Work-space analysis
- Repositioning accuracy (Hysteresis)
- Modification of tip section curvature

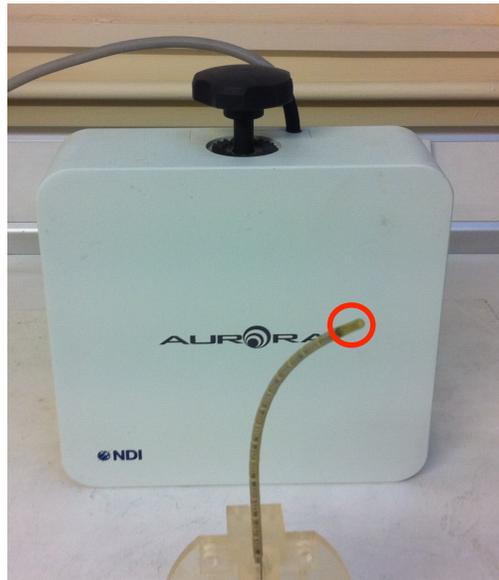
2. MRI-phantom experiments

- 1.5 Tesla MRI (Philips Achieva)
- Real-time SSFP in 3 orientations (TR/TE=3.2/1.6ms, 1.5mm, SENSE=2 6 frames/second)
- MR-compatible steering
- MR-tracking

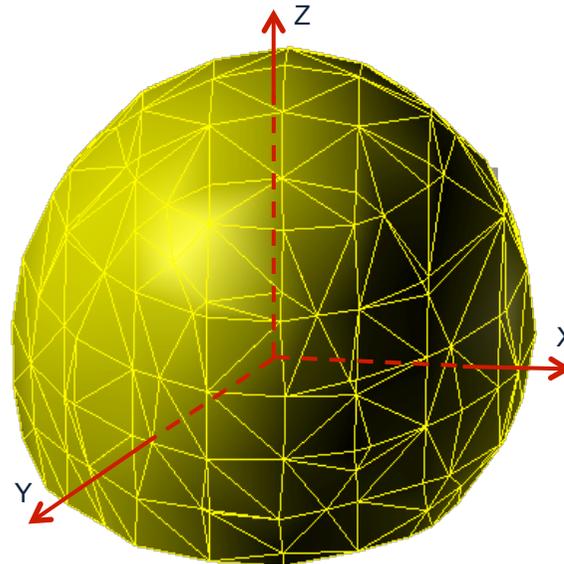


Results – Lab Tests Workspace & Hysteresis Analysis

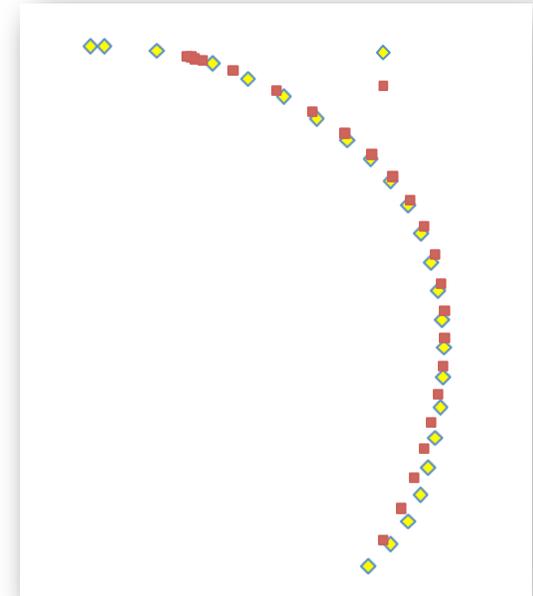
NDI Aurora® Magnetic Tracking System



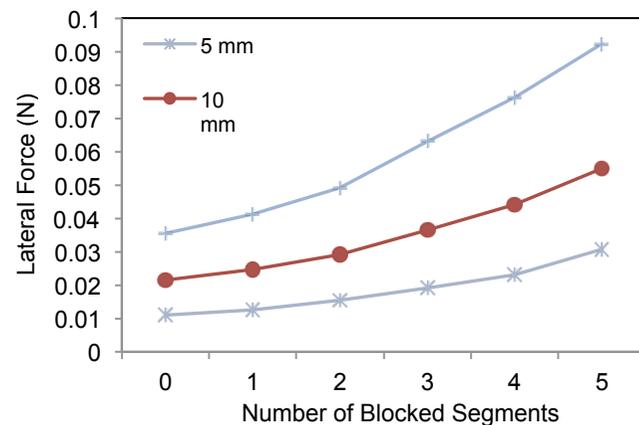
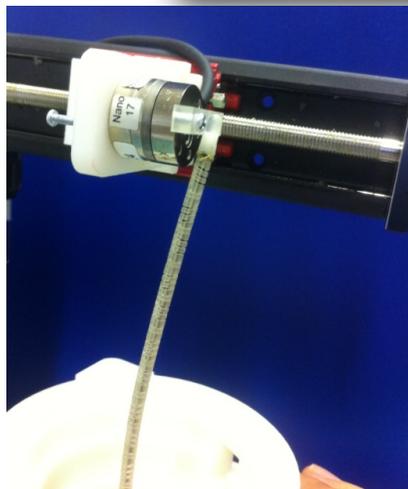
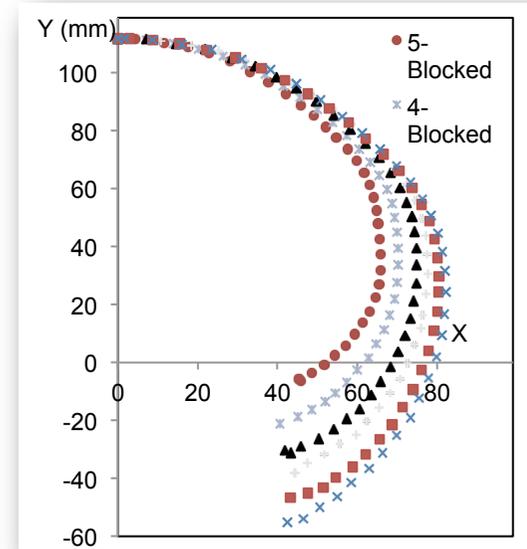
3D Workspace of the Catheter-Tip



Hysteresis Analysis in Large Deflection



Results – Lab Tests: Deflection Length Modification

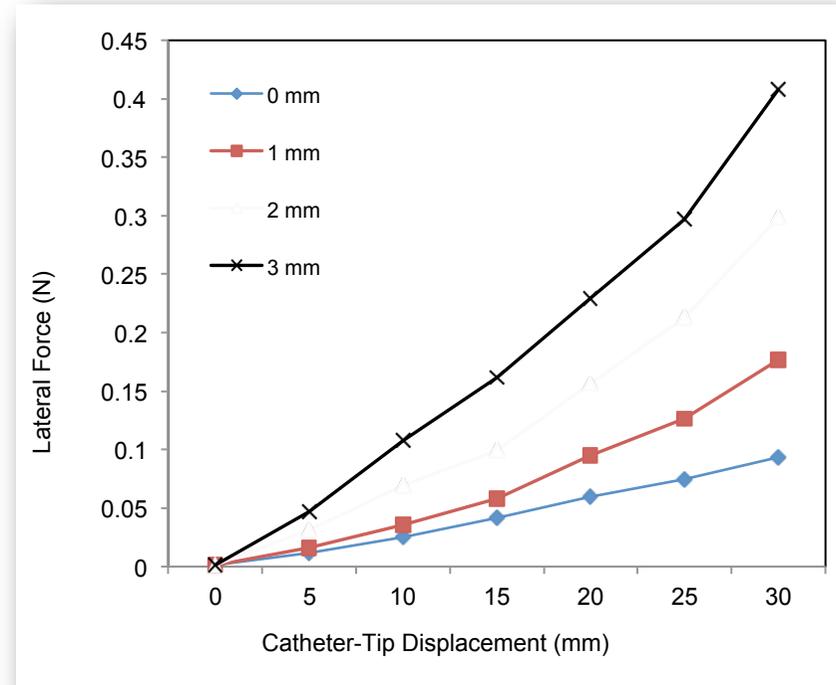
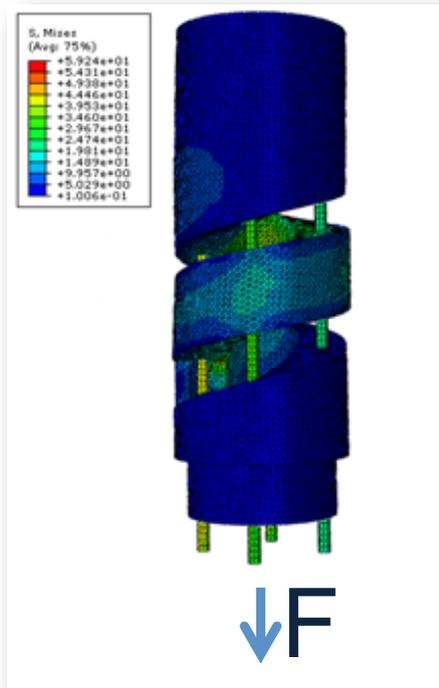


2D Tip Trajectory in Six Different Configuration

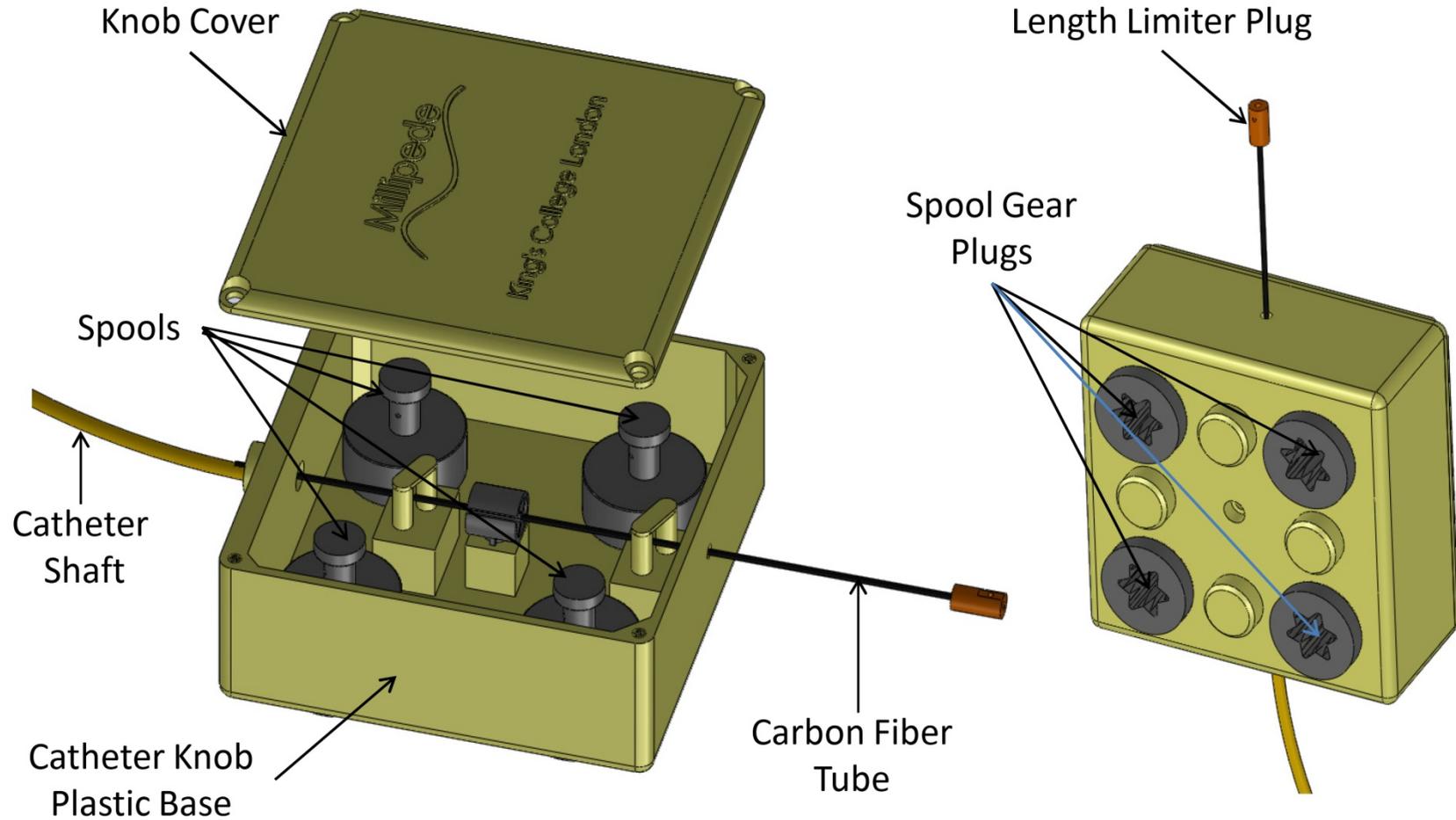
Lateral Forcibility Variation Based on Deflectable Length

Results – Lab Tests: Stiffness Adjustability

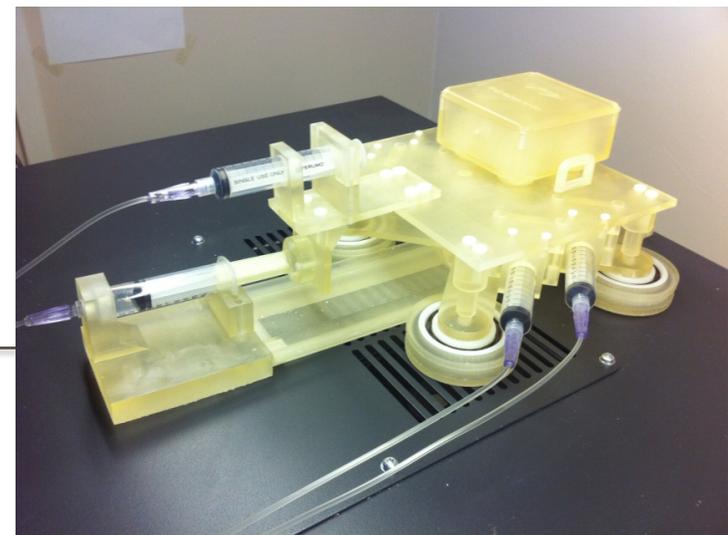
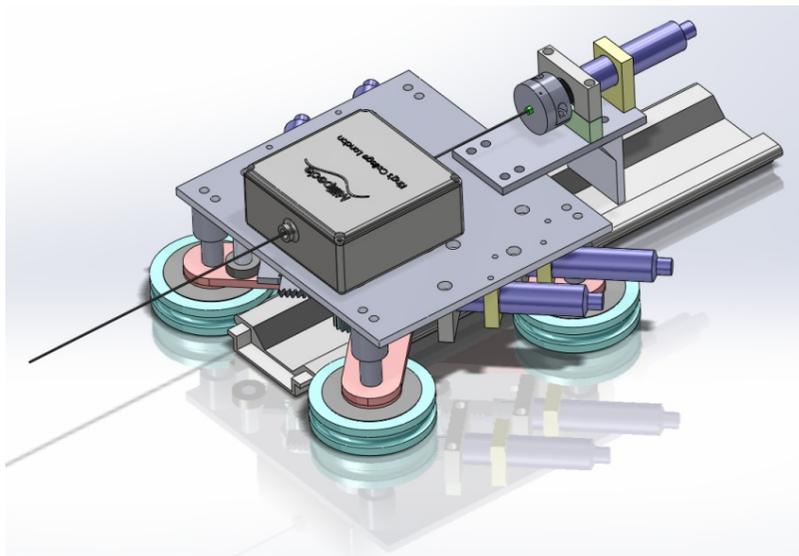
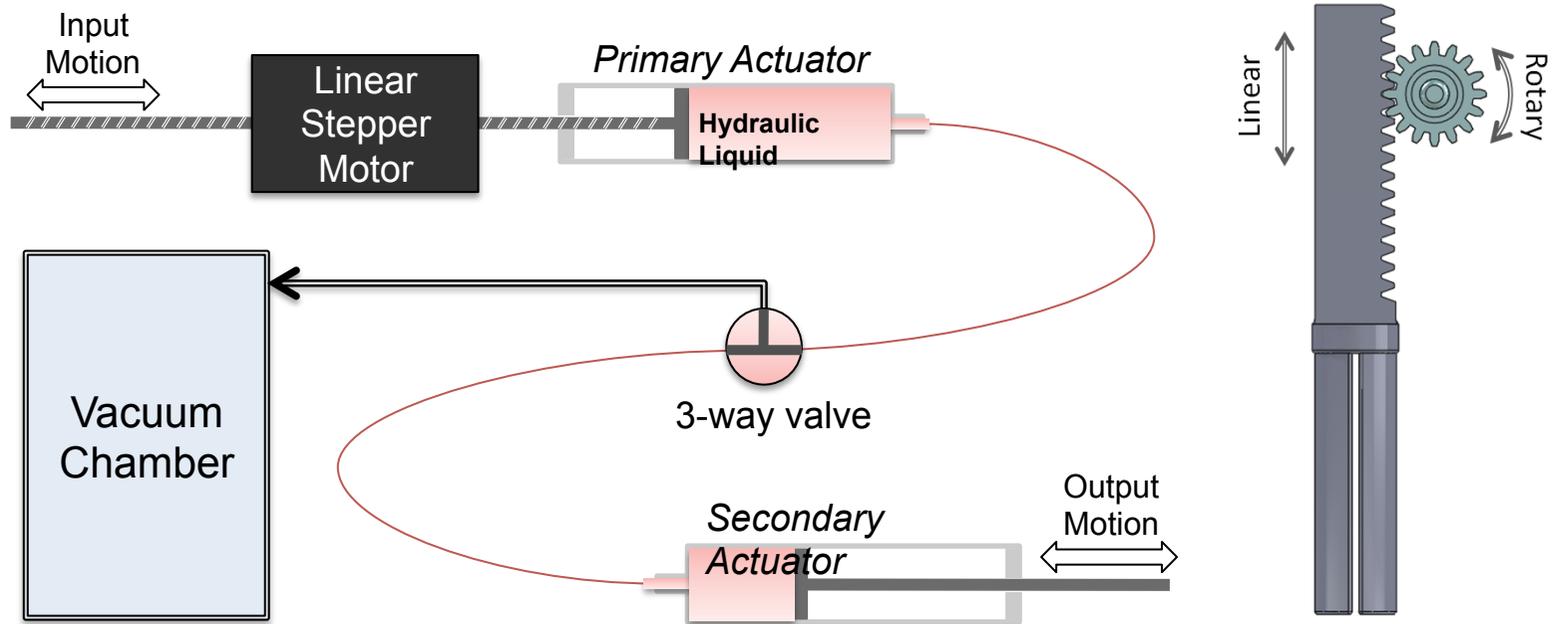
Simultaneous Tendon Tension Lateral Forcibility Diagram



Catheter Knob Design

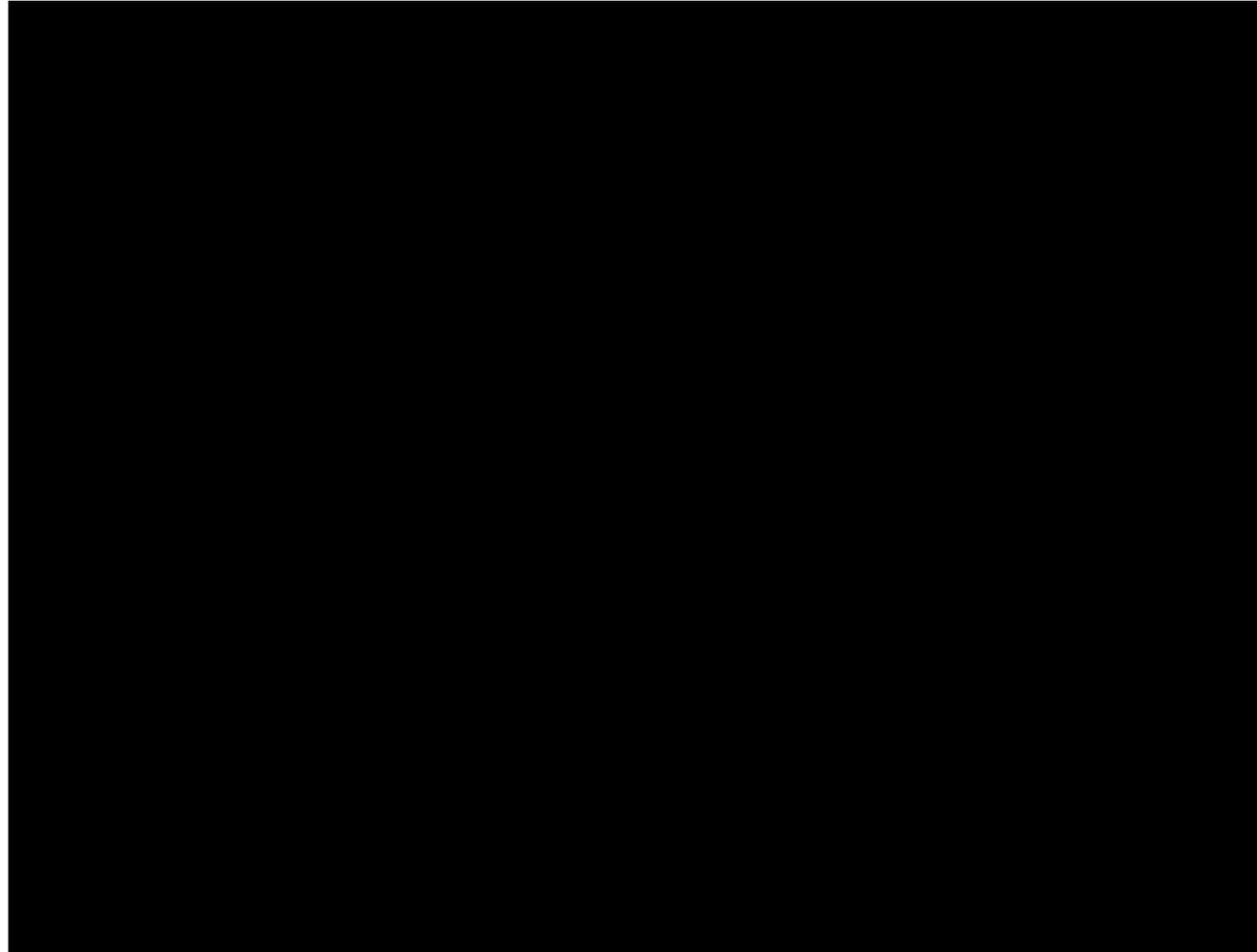


Passive Mater-Slave Hydraulic System



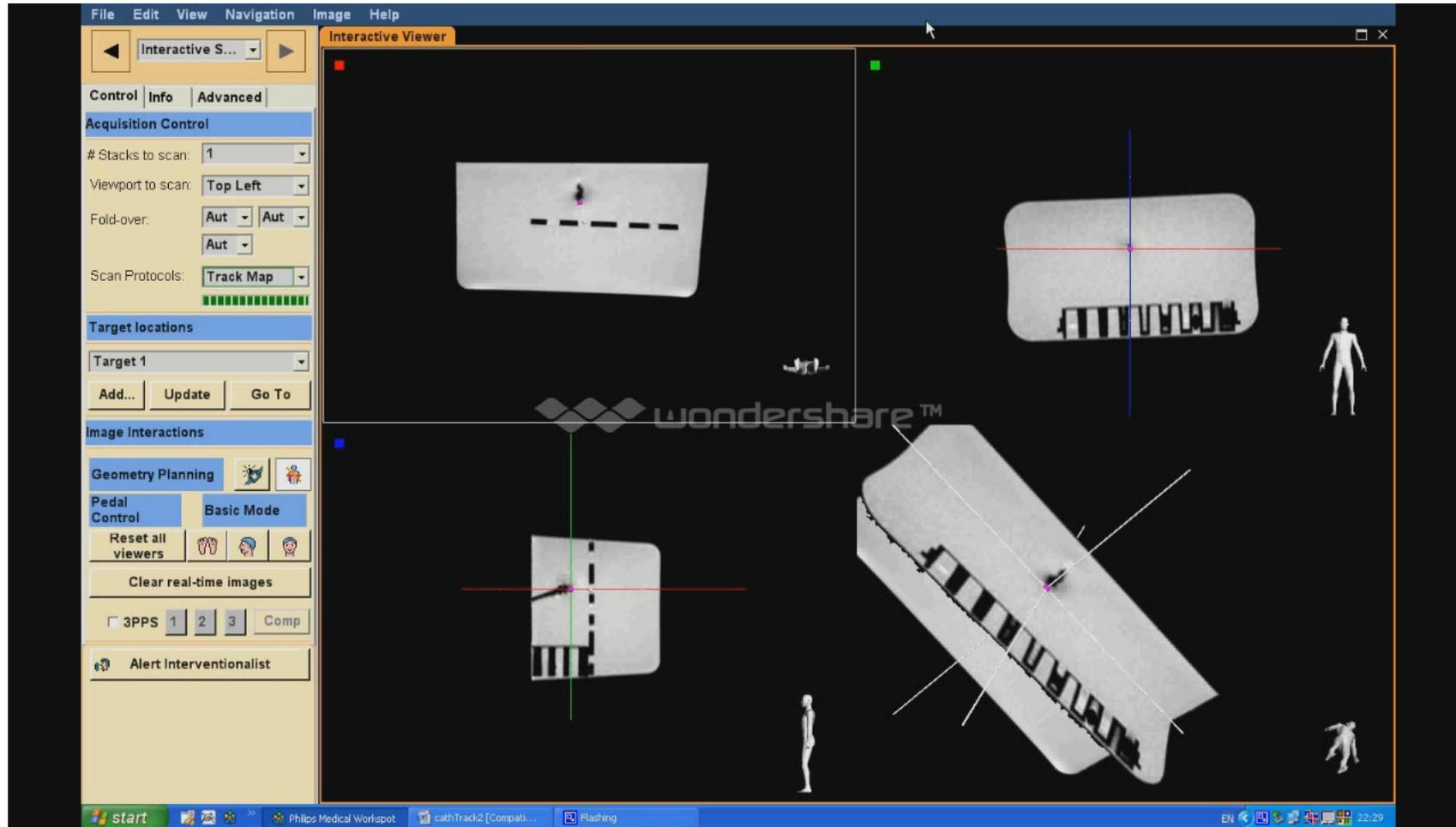
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Results – Real-time MRI



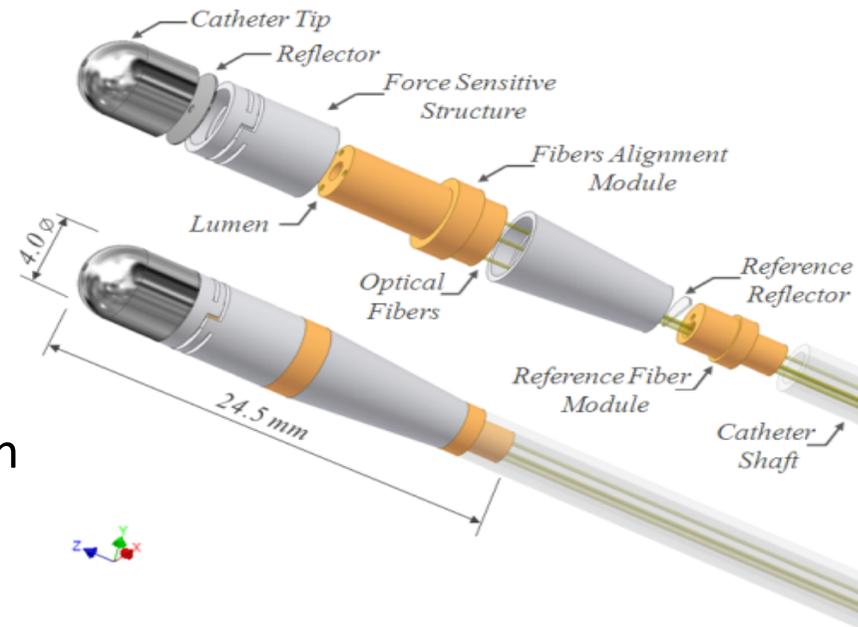
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MR Tracking Coil

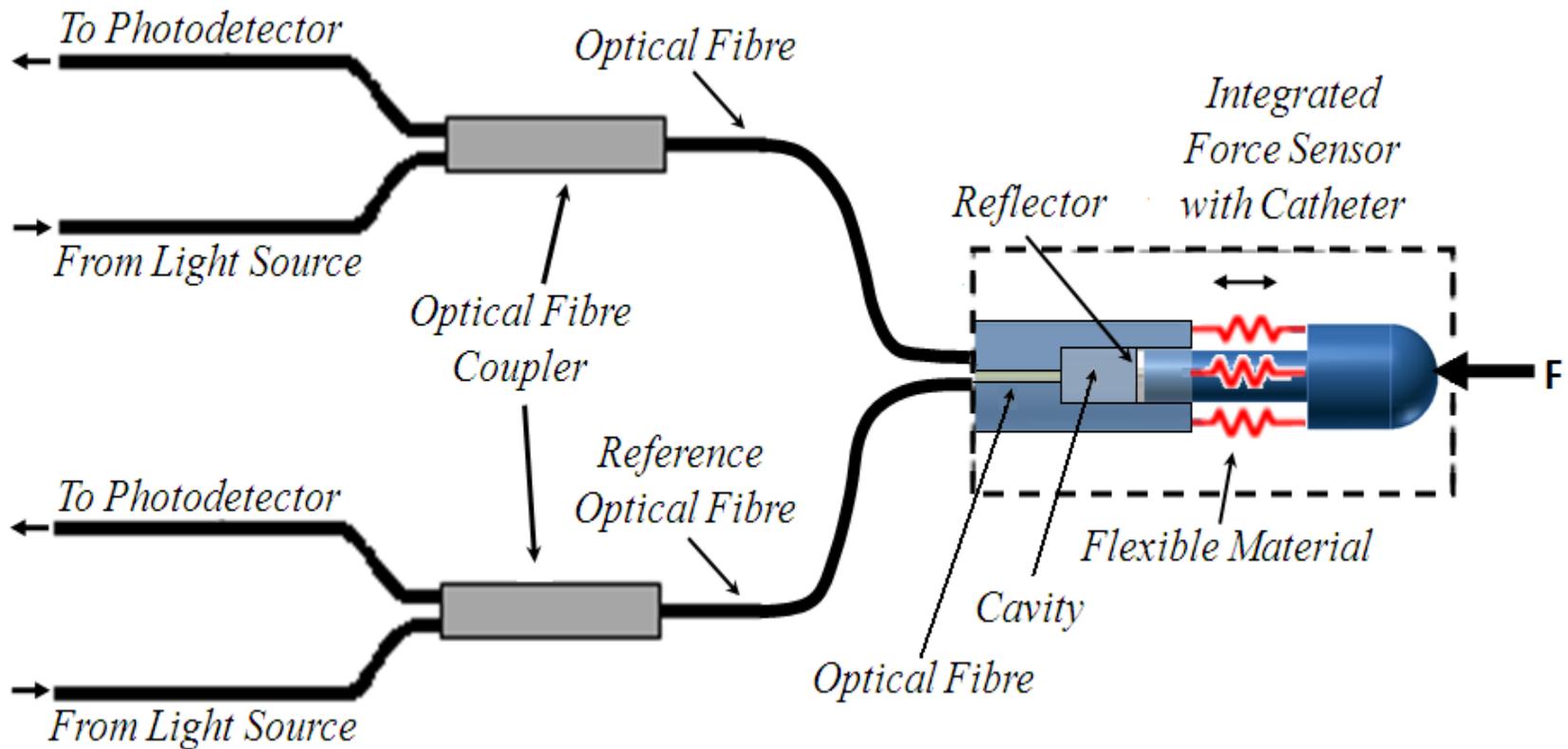


3 Axis Optical Fiber Catheter-tip Force Sensor

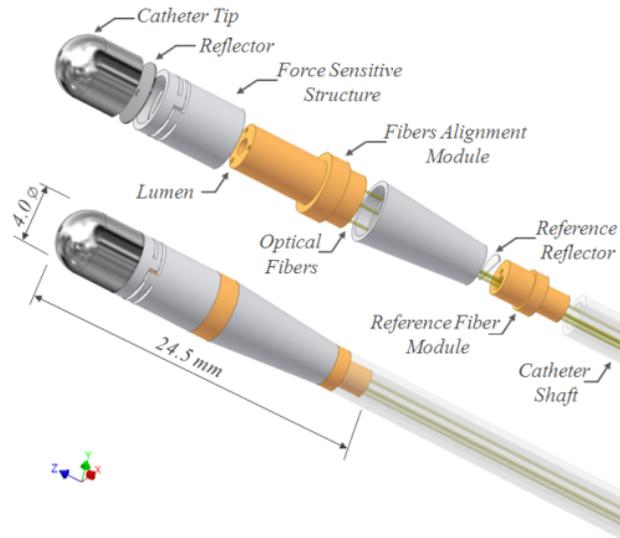
- MR-Compatible
- 3-Axis Miniaturized Force Sensor
- Accurate Measurement Based on Optical Fiber
- Force Range of 0 to 0.8 N
- Great Potential for Cardiac Ablation providing Contact Force Feedback



Catheter-Tip Force Sensing



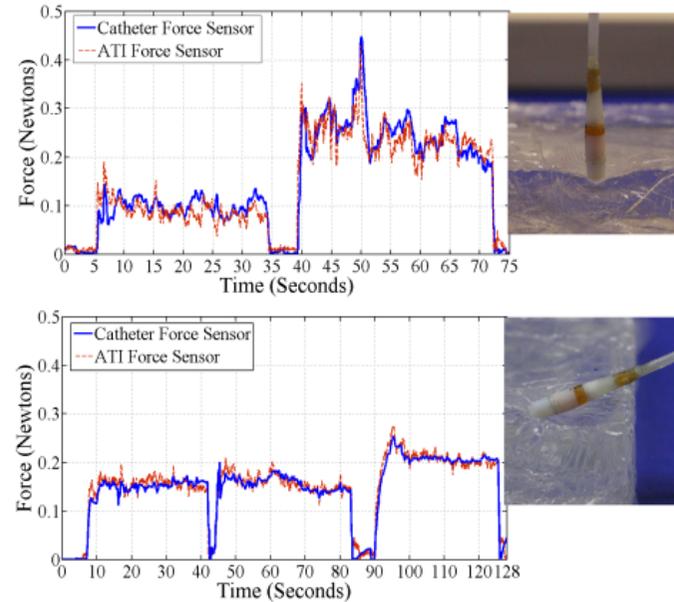
MR-Compatible Force Sensing Catheter



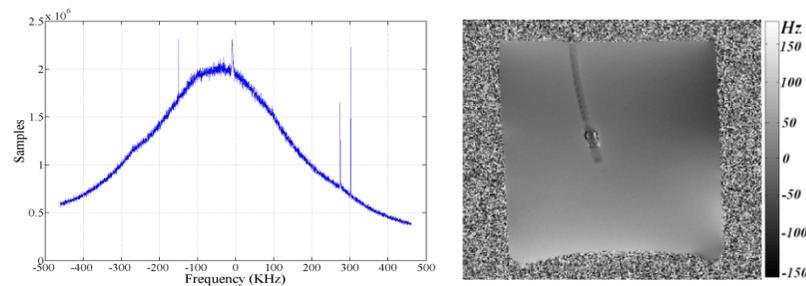
Fibre-optic, MRI-compatible, triaxial catheter-tip force sensor.



12Fr catheter-tip , triaxial force sensor.



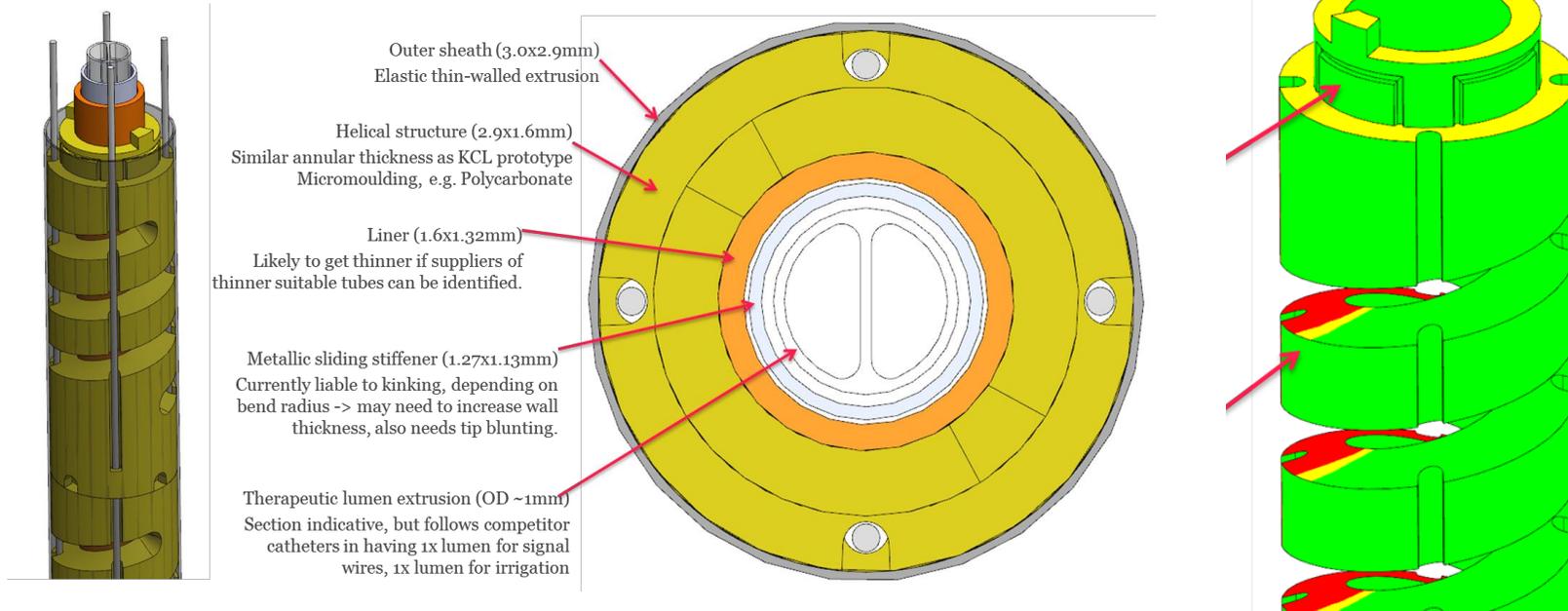
Comparison of the force signals of catheter-tip force sensor and the standard force sensor



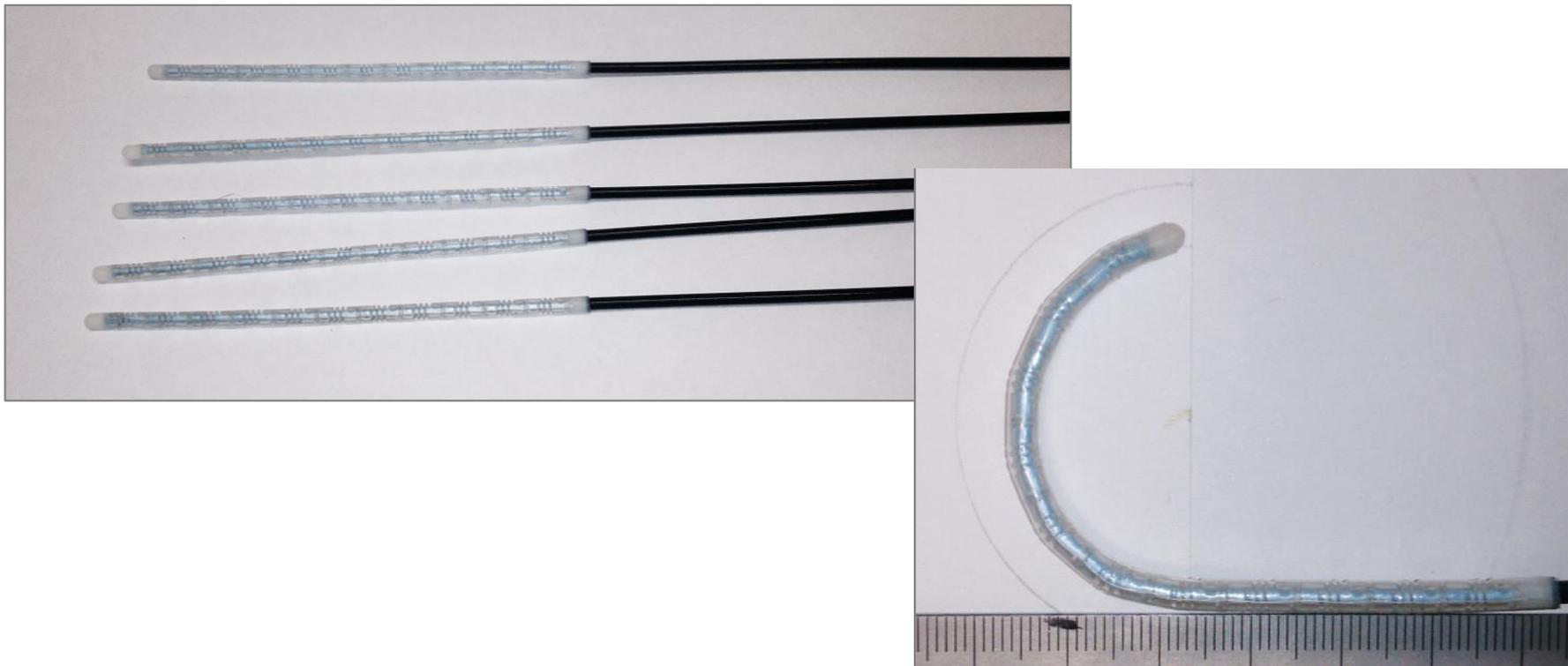
MR compatibility: RF-interference and B0-homogeneity

Next Steps

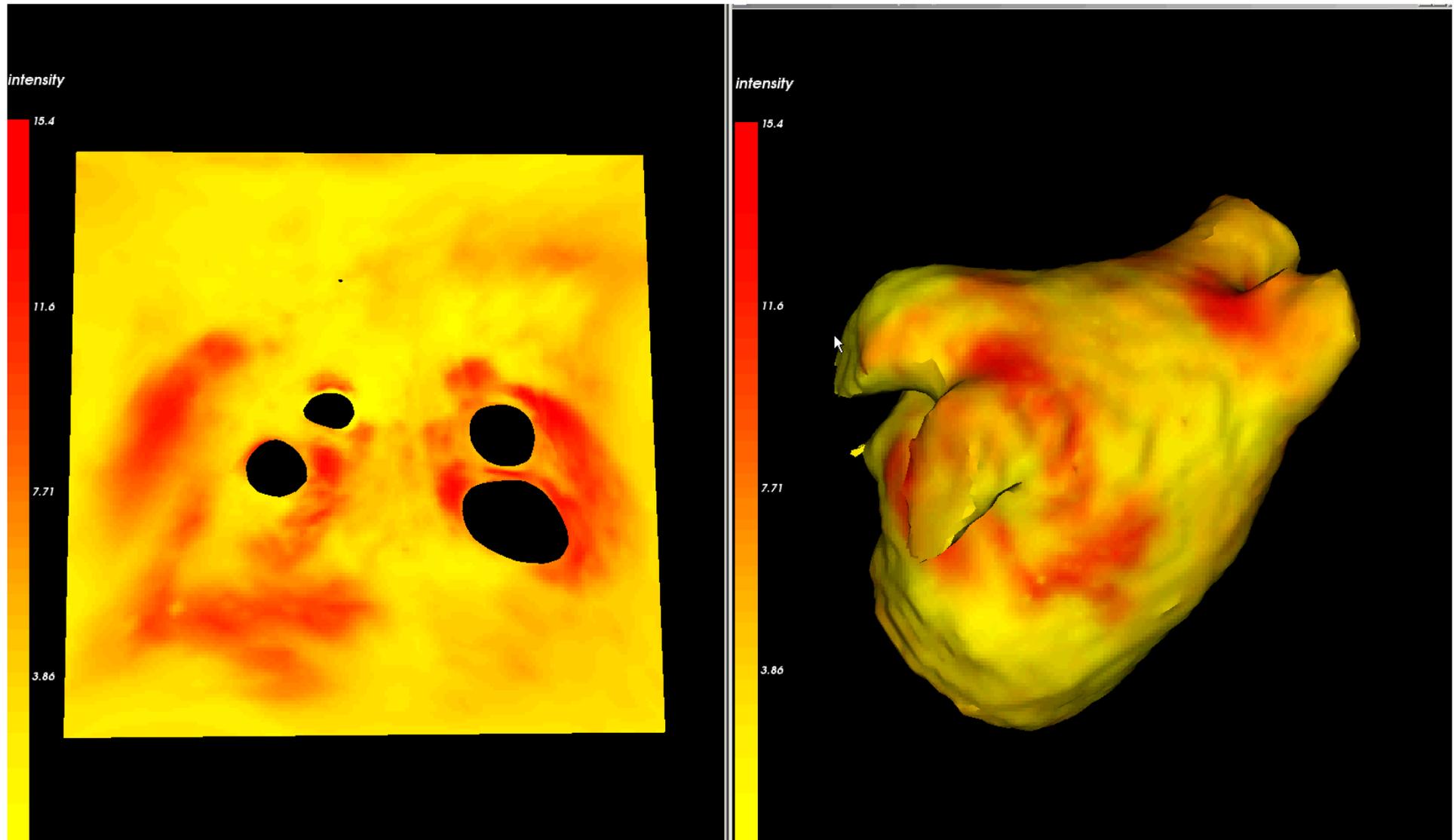
Simplified Production



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Left atrium surface flattening



Conclusion

- Feasibility of a new robotic steerable catheter principle
- MR-compatible devices and control system
- Integration of a MR-compatible force sensing system
- New planning and visualization is required for clinical translation

Acknowledgments

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- Philips Research

wellcome trust



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